High Resolution Gravity Field Models as Global Reference Surface for Heights

Thomas Gruber, Philipp Zingerle, Roland Pail, Xanthi Oikonomidou
Institute of Astronomical and Physical Geodesy
Technical University of Munich
Outline

High Resolution (HR) Models
- Models Overview
- The new XGM2019e Model
- Signal & Error Characteristics

Quality Assessment
- GNSS-Levelling as a Tool
- GNSS-Levelling Results

Summary & Conclusions
# HR Models Overview

<table>
<thead>
<tr>
<th>Model</th>
<th>Resolution</th>
<th>Satellite Data</th>
<th>Surface Data</th>
<th>Technique</th>
<th>Originator</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGM2008</td>
<td>2159 (ell.)</td>
<td>GRACE ITG-GRACE03S</td>
<td>DNSC07 Altimetry SS v18.1 Altimetry</td>
<td>d/o 359 full d/o 2159 BD</td>
<td>NGA, Pavlis et al, 2012</td>
</tr>
<tr>
<td></td>
<td>2190 (sph.)</td>
<td></td>
<td>NGA08 Land</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EIGEN6-C4</td>
<td>2190 (sph.)</td>
<td>GRACE-GRGS (10y) GOCE-DIR5 LAGEOS</td>
<td>DTU10 Altimetry EGM2008 Land</td>
<td>d/o 370 full d/o 2190 BD</td>
<td>GFZ/CNES Förste et al, 2014</td>
</tr>
<tr>
<td>GOCE-OGMOC</td>
<td>2190 (sph.)</td>
<td>GOCO05S</td>
<td>DTU13 Altimetry NGA16 Land (15')</td>
<td>XGM2016 (d/o 719 full) EIGEN6-C4 (720-2190)</td>
<td>IAPG-TUM Gruber et al, 2018</td>
</tr>
<tr>
<td>PGM2017</td>
<td>2159 (ell.)</td>
<td>GOCO05S</td>
<td>NGA (5’)</td>
<td>-</td>
<td>NGA, 2017</td>
</tr>
<tr>
<td></td>
<td>2190 (sph.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XGM2019e</td>
<td>5399 (ell.)</td>
<td>GOCO06S</td>
<td>DTU13 Altimetry NGA16 Land (15’)</td>
<td>d/o 719 full d/o 5399 BD</td>
<td>IAPG-TUM Zingerle et al, 2019 DOI: 10.5880/ICGEM.2019.007</td>
</tr>
<tr>
<td>XGM2019e_2159</td>
<td>5540 (sph.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XGM2019</td>
<td>2159 (ell.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2190 (sph.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>719 (ell.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>760 (sph.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**XGM2019e Model**

- Full normal equations up to d/o 719 (ell.) from NGA 15’ land/ocean data and GOCO06S.
- Block-Diagonal normal equations up to d/o 5399 (ell.) from DTU13 altimetric gravity over oceans and topographic gravity over land.

---

**Data Coverage**

**Weighting Scheme**

**Signal and Error Degree Variances (SQRT)**
HR Models Signal Characteristics
HR Models Signal Characteristics

- Signal differences to EGM2008 exhibit the impact of new information in the high resolution gravity field models.
- Up to d/o 60 hardly any difference, indicating that all models are similar in this range and dominated by GRACE.
- Between d/o 60 and 200 in global average most impact from adding GOCE data (about 80% of total impact).
- Above d/o 200 impact from new surface data visible (20% of total impact).
HR Models Error Characteristics

![Error Characteristics Diagram](image)
Error Assessment by GNSS-Levelling

- Compute height anomaly at GNSS-levelling station from global model up to degree and order N.
- Estimate **omitted signal from existing HR-model** from degree N+1 to 2160 (2190) (EIGEN6C4 was used in this study).
- Estimated **omitted signal above 2160 from topographic gravity field model**. (ERTM2160, Hirt et al, 2014)
- If necessary, **convert from height anomalies to geoid undulations** (Rapp, 1997).
- Compare with geoid height / height anomaly at GNSS-levelling station computed from \( h-H \)
- Systematic differences between model and observed geoid heights are possible (definition of local height systems).
- Apply **correction surface** (planar fit to differences)
- Analyse corrected geoid height differences
## GNSS-Levelling Data Sets

<table>
<thead>
<tr>
<th>Region</th>
<th>No. Points</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>197</td>
<td>Geoscience Australia, 2003</td>
</tr>
<tr>
<td>Brazil</td>
<td>683</td>
<td>Brazilian Institute of Geography and Statistics - IBGE, 2012</td>
</tr>
<tr>
<td></td>
<td>1287</td>
<td>Brazilian Institute of Geography and Statistics - IBGE, 2019</td>
</tr>
<tr>
<td>Brazil 2012</td>
<td>579</td>
<td>National Resources of Canada (NRCan), via US National Geodetic Survey (NGS), 2012</td>
</tr>
<tr>
<td>Brazil 2007</td>
<td>2576</td>
<td>National Resources of Canada (NRCan), via US National Geodetic Survey (NGS), 2007</td>
</tr>
<tr>
<td>Europe Various Countries, EUREF EUVN</td>
<td>1233</td>
<td>Bundesamt für Kartographie und Geodäsie, Frankfurt/Main, 2007</td>
</tr>
<tr>
<td>Germany 2007 (DHHN92)</td>
<td>675</td>
<td>Bundesamt für Kartographie und Geodäsie, Frankfurt/Main, 2003</td>
</tr>
<tr>
<td>Germany 2016 (DHHN16)</td>
<td>470</td>
<td>© GeoBasis-DE / Geobasis NRW, 2018</td>
</tr>
<tr>
<td>Great Britain</td>
<td>177</td>
<td>UK Ordnance Survey, 2011</td>
</tr>
<tr>
<td>Greece Mainland</td>
<td>1542</td>
<td>Aristotle University of Thessaloniki, 2016</td>
</tr>
<tr>
<td>Japan</td>
<td>837</td>
<td>Japanese Geographical Survey Institute, 2003</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>382</td>
<td>King Abdulaziz City for Science and Technology KACST, 2012</td>
</tr>
<tr>
<td>USA</td>
<td>24872</td>
<td>National Geodetic Survey, 2012</td>
</tr>
</tbody>
</table>

SIRGAS 2019, Rio de Janeiro, 12.11.2019
Error Assessment by GNSS-Levelling

Omission Error Estimate from Degree Variance Models

- Degree 200 ≈ 30 cm
- Degree 2160 ≈ 3 cm

Per degree

From degree (to infinity)
Error Assessment by GNSS-Levelling

Omission Error Estimate from Topographic Gravity Field Model (ERTM2160)

- up to ±10-20 cm in mountaineous areas
Error Assessment by GNSS-Levelling

Conversion Height Anomalies to Geoid Undulations (if needed)

Japan

USA-Colorado

up to ±1-2 m in larger mountaineous areas
Error Assessment by GNSS-Levelling

Correction Surface (for XGM2019e d/o 2190)

XGM2019e vs. Germany2016  Correction Surface  Residuals
Error Assessment by GNSS-Levelling

Correction Surface (for XGM2019e d/o 2190)

XGM2019e vs. USA2012

Correction Surface

Residuals
Error Assessment by GNSS-Levelling

Correction Surface (for XGM2019e d/o 2190)

XGM2019e vs. Brazil2019  Correction Surface  Residuals
Error Assessment by GNSS-Levelling

Correction Surface (for XGM2019e d/o 2190)

XGM2019e vs. Brazil2019 (subset not including data from Amapa, Amazonas, Rondonia, Roraima)

Correction Surface

Residuals
## GNSS-Levelling Results

### Overview Height Differences (d/o 2190)

<table>
<thead>
<tr>
<th>GNSS-levelling Dataset</th>
<th>No.</th>
<th>EGM2008</th>
<th>EIGEN6-C4</th>
<th>GOCE-OGMOC</th>
<th>PGM2017</th>
<th>XGM2019e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska</td>
<td>109</td>
<td>25.7</td>
<td>25.4</td>
<td>25.3</td>
<td>23.9</td>
<td>25.3</td>
</tr>
<tr>
<td>Australia</td>
<td>197</td>
<td>17.9</td>
<td>17.5</td>
<td>17.6</td>
<td>17.6</td>
<td>17.6</td>
</tr>
<tr>
<td>Brazil 2012</td>
<td>683</td>
<td>33.7</td>
<td>27.6</td>
<td>26.6</td>
<td>26.6</td>
<td>26.2</td>
</tr>
<tr>
<td>Brazil 2019 (complete)</td>
<td>1287</td>
<td>40.0</td>
<td>35.2</td>
<td>33.9</td>
<td>33.7</td>
<td>33.5</td>
</tr>
<tr>
<td>Brazil 2019 (subset)</td>
<td>1180</td>
<td>27.0</td>
<td>21.0</td>
<td>18.4</td>
<td>18.4</td>
<td>18.5</td>
</tr>
<tr>
<td>Canada</td>
<td>579</td>
<td>8.1</td>
<td>7.7</td>
<td>7.6</td>
<td>7.6</td>
<td>7.9</td>
</tr>
<tr>
<td>Germany 2016</td>
<td>470</td>
<td>1.8</td>
<td>1.5</td>
<td>1.7</td>
<td>2.1</td>
<td>2.6</td>
</tr>
<tr>
<td>Greece</td>
<td>1542</td>
<td>13.9</td>
<td>12.4</td>
<td>13.0</td>
<td>13.1</td>
<td>13.7</td>
</tr>
<tr>
<td>Japan</td>
<td>837</td>
<td>7.4</td>
<td>6.5</td>
<td>6.3</td>
<td>6.3</td>
<td>7.8</td>
</tr>
<tr>
<td>Mexico</td>
<td>744</td>
<td>30.1</td>
<td>29.9</td>
<td>28.3</td>
<td>28.6</td>
<td>28.7</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>29</td>
<td>2.7</td>
<td>3.1</td>
<td>2.8</td>
<td>3.2</td>
<td>6.0</td>
</tr>
<tr>
<td>UK</td>
<td>177</td>
<td>4.2</td>
<td>3.7</td>
<td>3.7</td>
<td>3.6</td>
<td>4.6</td>
</tr>
<tr>
<td>USA</td>
<td>24872</td>
<td>9.4</td>
<td>9.3</td>
<td>9.1</td>
<td>9.2</td>
<td>9.7</td>
</tr>
</tbody>
</table>

RMS around mean after subtracting correction surface (all points) [cm]
GNSS-Levelling Results

RMS of Geoid Differences per Data Set for Different Model Resolutions

Germany 2016

USA 2012
GNSS-Levelling Results

RMS of Geoid Differences per Data Set for Different Model Resolutions

Japan

Brazil 2019 (subset not including data from Amapa, Amazonas, Rondonia, Roraima)
The mean dynamic topography is computed by subtracting the unfiltered ocean geoid model from the unfiltered CNES/CLS 2015 mean sea surface.
Ocean Mean Dynamic Topography (MDT)

Geostrophic velocities from CNES/CLS2015 MSS minus EGM2008

Geostrophic velocities from CNES/CLS2015 MSS minus XGM2019e

From the MDT geostrophic current velocities are computed by horizontal derivatives. Both MDT’s are filtered identically before differentiation.
Summary & Conclusions

High Resolution Models

- A new ultra high resolution model up to degree and order 5540 has been computed – XGM2019e is completely independent from any a-priori high resolution model.
- In global average most improvement wrt. EGM2008 from GOCE data (70%-80% up to d/o 200) and some improvement from better surface data (20%-30% up to full resolution).

HR Model Performance

- Very difficult to distinguish between errors caused by levelling, GNSS, global model and corrections. For a high quality GNSS-leveling data set (e.g. Germany) differences between 1.5 and 2.5 cm can be reached.
- XGM2019e performance over continents degraded for degrees above 719 due to modelling the signal purely from a topography model. But, degradation only at a level of a few cm due to missing observed gravity data.

HR Model as Height Reference Surface

- Depending on the roughness of surface topography, global models deliver an equipotential surface as global height reference at a level of 1 to 10 cm in terms of accuracy.
- For areas with less good gravity infrastructure such global models represent the best choice.
References & Acknowledgement

References:
- Thomas Gruber and Martin Willberg: Signal and Error Assessment of GOCE-based High Resolution Gravity Field Models; accepted for publication by Journal of Geodetic Science, Ms. No. JGS-D-18-00023, 2019
- Zingerle, Philipp; Pail, Roland; Gruber, Thomas; Oikonomidou, Xanthi (2019): The experimental gravity field model XGM2019e. GFZ Data Services. http://doi.org/10.5880/ICGEM.2019.007

GNSS-Levelling Data have been provided by:
- Australia: Geoscience Australia, 2003
- Brazil: Brazilian Institute of Geography and Statistics - IBGE, Directorate of Geosciences - DGC, Coordination of Geodesy – CGED, 2012, 2019
- Canada: National Resources of Canada (NRCan), via National Geodetic Survey, 2012
- Europe Various Countries, EUREF EUVN: Bundesamt für Kartographie und Geodäsie, Frankfurt/Main, 2007
- Germany: Bundesamt für Kartographie und Geodäsie, Frankfurt/Main, 2007
- Great Britain: UK Ordnance Survey, 2011
- Greece: Aristotle University of Thessaloniki, 2016
- Japan: Japanese Geographical Survey Institute, 2003
- Saudi Arabia: King Abdulaziz City for Science and Technology KACST, 2012
- USA: National Geodetic Survey, 2012
Thanks for Your Attention
# GNSS-Levelling Results Brazil

## Overview Height Differences (d/o 2190)

<table>
<thead>
<tr>
<th>GNSS-levelling Dataset</th>
<th>No.</th>
<th>EGM2008</th>
<th>EIGEN6-C4</th>
<th>GOCE- OGMOC</th>
<th>PGM2017</th>
<th>XGM2019e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil 2019 (complete)</td>
<td>1287</td>
<td>40.0</td>
<td>35.2</td>
<td>33.9</td>
<td>33.7</td>
<td>33.5</td>
</tr>
<tr>
<td>Brazil 2019 (subset)*</td>
<td>1180</td>
<td>27.0</td>
<td>21.0</td>
<td>18.4</td>
<td>18.4</td>
<td>18.5</td>
</tr>
<tr>
<td>Alagoas</td>
<td>6</td>
<td>15.6</td>
<td>8.7</td>
<td>13.6</td>
<td>12.6</td>
<td>11.5</td>
</tr>
<tr>
<td>Amapa</td>
<td>65</td>
<td>19.9</td>
<td>11.8</td>
<td>11.7</td>
<td>11.9</td>
<td>10.5</td>
</tr>
<tr>
<td>Amazonas</td>
<td>16</td>
<td>28.1</td>
<td>20.9</td>
<td>12.9</td>
<td>15.4</td>
<td>13.3</td>
</tr>
<tr>
<td>Bahia</td>
<td>176</td>
<td>14.3</td>
<td>15.3</td>
<td>14.3</td>
<td>14.8</td>
<td>15.2</td>
</tr>
<tr>
<td>Ceara</td>
<td>82</td>
<td>7.9</td>
<td>9.2</td>
<td>8.5</td>
<td>8.6</td>
<td>8.4</td>
</tr>
<tr>
<td>Distrito Federal</td>
<td>26</td>
<td>8.6</td>
<td>5.8</td>
<td>7.0</td>
<td>6.0</td>
<td>5.8</td>
</tr>
<tr>
<td>Espirito Santo</td>
<td>17</td>
<td>31.1</td>
<td>18.3</td>
<td>19.5</td>
<td>19.6</td>
<td>19.9</td>
</tr>
<tr>
<td>Goias</td>
<td>107</td>
<td>18.0</td>
<td>13.3</td>
<td>9.0</td>
<td>8.6</td>
<td>8.9</td>
</tr>
<tr>
<td>Maranhao</td>
<td>40</td>
<td>13.9</td>
<td>12.8</td>
<td>9.1</td>
<td>9.6</td>
<td>9.4</td>
</tr>
<tr>
<td>Mato Grosso do Sul</td>
<td>54</td>
<td>12.9</td>
<td>11.3</td>
<td>9.2</td>
<td>8.8</td>
<td>9.5</td>
</tr>
<tr>
<td>Mato Grosso</td>
<td>56</td>
<td>76.4</td>
<td>38.2</td>
<td>20.9</td>
<td>21.6</td>
<td>21.8</td>
</tr>
<tr>
<td>Minas Gerais</td>
<td>155</td>
<td>21.8</td>
<td>17.3</td>
<td>15.1</td>
<td>15.1</td>
<td>15.5</td>
</tr>
<tr>
<td>Para</td>
<td>24</td>
<td>62.1</td>
<td>47.6</td>
<td>46.8</td>
<td>46.2</td>
<td>46.0</td>
</tr>
</tbody>
</table>

RMS around mean after subtracting correction surface (all points) [cm]

*excluding GPS-levelling points from Amapa, Amazonas, Rondonia, Roraima
### GNSS-Levelling Results Brazil

#### Overview Height Differences (d/o 2190)

<table>
<thead>
<tr>
<th>GNSS-levelling Dataset</th>
<th>No.</th>
<th>EGM2008</th>
<th>EIGEN6-C4</th>
<th>GOCE-OGMOC</th>
<th>PGM2017</th>
<th>XGM2019e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil 2019 (complete)</td>
<td>1287</td>
<td>40.0</td>
<td>35.2</td>
<td>33.9</td>
<td>33.7</td>
<td>33.5</td>
</tr>
<tr>
<td>Brazil 2019 (subset)*</td>
<td>1180</td>
<td>27.0</td>
<td>21.0</td>
<td>18.4</td>
<td>18.4</td>
<td>18.5</td>
</tr>
<tr>
<td>Paraiba</td>
<td>12</td>
<td>22.9</td>
<td>12.8</td>
<td>9.4</td>
<td>9.3</td>
<td>9.2</td>
</tr>
<tr>
<td>Parana</td>
<td>53</td>
<td>16.6</td>
<td>15.2</td>
<td>14.9</td>
<td>15.3</td>
<td>15.0</td>
</tr>
<tr>
<td>Pernambuco</td>
<td>29</td>
<td>25.8</td>
<td>17.0</td>
<td>11.3</td>
<td>10.5</td>
<td>10.4</td>
</tr>
<tr>
<td>Piaui</td>
<td>44</td>
<td>15.5</td>
<td>9.9</td>
<td>10.2</td>
<td>10.5</td>
<td>10.4</td>
</tr>
<tr>
<td>Rio Grande do Norte</td>
<td>16</td>
<td>9.3</td>
<td>5.5</td>
<td>4.6</td>
<td>3.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Rio Grande do Sul</td>
<td>66</td>
<td>16.1</td>
<td>15.4</td>
<td>15.3</td>
<td>15.6</td>
<td>15.3</td>
</tr>
<tr>
<td>Rio de Janeiro</td>
<td>59</td>
<td>20.4</td>
<td>18.4</td>
<td>10.3</td>
<td>10.2</td>
<td>9.4</td>
</tr>
<tr>
<td>Rondonia</td>
<td>10</td>
<td>31.4</td>
<td>22.3</td>
<td>14.7</td>
<td>14.9</td>
<td>14.9</td>
</tr>
<tr>
<td>Roraima</td>
<td>16</td>
<td>24.5</td>
<td>10.8</td>
<td>8.2</td>
<td>9.4</td>
<td>9.1</td>
</tr>
<tr>
<td>Santa Caterina</td>
<td>32</td>
<td>10.5</td>
<td>9.1</td>
<td>10.1</td>
<td>9.5</td>
<td>9.3</td>
</tr>
<tr>
<td>Sao Paulo</td>
<td>102</td>
<td>22.2</td>
<td>22.4</td>
<td>21.2</td>
<td>21.1</td>
<td>21.1</td>
</tr>
<tr>
<td>Sergipe</td>
<td>4</td>
<td>19.5</td>
<td>4.7</td>
<td>4.6</td>
<td>7.6</td>
<td>7.4</td>
</tr>
<tr>
<td>Tocantins</td>
<td>20</td>
<td>22.8</td>
<td>14.7</td>
<td>8.4</td>
<td>8.0</td>
<td>7.8</td>
</tr>
</tbody>
</table>

*exlifting GPS-levelling points from from Amapa, Amazonas, Rondonia, Roraima

RMS around mean after subtracting correction surface (all points) [cm]

SIRGAS 2019, Rio de Janeiro, 12.11.2019
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Alagoas (6 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Amapa (65 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Amazonas (16 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Bahia (176 Points)
RMS of Geoid Differences per Data Set for Different Model Resolutions

Ceará (82 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Distrito Federal (26 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Espírito Santo (17 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Goias (107 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Maranhão (40 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Mato Grosso do Sul (54 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Mato Grosso (56 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Minas Gerais (155 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Para (24 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Paraiba (12 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Parana (53 Points)
GNSS-levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Pernambuco (29 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Piaui (44 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Rio Grande do Norte (16 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Rio Grande do Sul (66 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Rio de Janeiro (59 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Rondonia (10 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Roraima (16 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Santa Caterina (32 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Sao Paulo (102 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Sergipe (4 Points)
GNSS-Levelling Results Brazil

RMS of Geoid Differences per Data Set for Different Model Resolutions

Tocantins (20 Points)